Project done on behalf of
Gulf Power Limited

AIR QUALITY IMPACT ASSESSMENT FOR A MEDIUM SPEED DIESEL (MSD) THERMAL POWER PLANT NEAR NAIROBI, KENYA

Report No.: APP/11/GPL-01 Rev 2

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REPORT DETAILS

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Client	Gulf Power Limited
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Notice	Airshed Planning Professionals (Pty) Ltd is a consulting company located in Midrand, South Africa, specialising in all aspects of air quality, ranging from nearby neighborhood concerns to regional air pollution impacts. The company originated in 1990 as Environmental Management Services, which amalgamated with its sister company, Matrix Environmental Consultants, in 2003.
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Acknowledgements	The authors would like to express their appreciation to Sanjay Gandhi of Nutek Solutions Ltd for providing data and technical input.

EXECUTIVE SUMMARY

INTRODUCTION

Airshed Planning Professionals (Pty) Ltd was contracted by Gulf Power Limited to conduct an air quality study for medium speed diesel (MSD) thermal power plant situated about 30km south east of Nairobi, Kenya.

The main aim of this investigation was to determine the impacts from the proposed power plant on the surrounding environment and human health.

Terms of Reference

The tasks involved for the air quality impact assessment for the proposed MSD thermal power plant included:

- Legal review of environmental regulations relating to air quality (Kenya and World Bank);
- Meteorological and topographical data;
- Emissions inventory based on design criteria;
- Dispersion simulation;
- Compliance assessment;
- Compilation of a comprehensive report.

Legal Requirements

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. EC limits were used to assess the proposed power plant, and to determine acceptable ambient concentrations at which the public can be exposed to ensure minimal risk to all.

IMPACT EVALUATION

In assessing atmospheric impacts due to the proposed MSD thermal power plant, an emissions inventory was undertaken, atmospheric dispersion modelling conducted and predicted air pollutant concentrations evaluated.

Emissions Inventory

An emission inventory was compiled for the proposed MSD thermal power plant under normal operating conditions. The following scenario was simulated:

- 2 segmented stacks (each segmented stack (with a calculated equivalent diameter) consists of a group of 5 stack pipes (one stack pipe per 8MW unit)) at 30m stack heights; and sulphur content of fuel of 2%.

Dispersion Results

The prevailing wind field for the Nairobi site as taken from the Lakes Environmental MM5 data is predominantly northeast.

The terrain is fairly flat in the vicinity of the site, with an elevation of approximately 1516 m. Lukenya hill is located over 5km east of the site at an elevation of approximately 1828 m.

Summary of the predicted ground level concentrations are provided in Table 1.

Table 1: Summary of the predicted ground level concentrations.

Pollutant	Averaging period	EC limits (µg/m³)	Predicted concentrations (µg/m³) and frequencies of exceedences at the sensitive receptors					
			Athi River		Housing Estate		Lukenya School	
			ADMS	AERMOD	ADMS	AERMOD	ADMS	AERMOD
SO_2	Highest hourly	350	160	90	300	130	55	**800**
	Hourly FOE	24	-	-	-	-	-	**24**
	Highest daily	125	40	23	27	27	5	60
	Daily FOE	3	-	-	-	-	-	-
NO_2	Highest hourly	200	100	55	175	75	34	**450**
	Hourly FOE	18	-	-	-	-	-	**24**
	Annual average	40	5.5	4	0.5	5	0.3	4
PM_{10}	Highest daily	50	1.7	1	1	1.2	0.2	2.5
	Annual average	40	0.18	0.14	0.02	0.18	0.01	0.13

Notes:
Frequency of Exceedance of EC limits shown in bold.

CONCLUSIONS

- At the nearest sensitive receptor of Athi River and the housing estate, none of the EC limit values are predicted to be exceeded.
- AERMOD predicts exceedences of the SO_2 and NO_2 hourly limits at Lukenya school with the frequency of exceedence being equal to the limit for SO_2 and slightly over the limit for NO_2
- ADMS is slightly more conservative than AERMOD in the vicinity of the plant, thus near-site with AERMOD being more conservative further away at the elevated areas such as Lukenya Hill area.

The following was recommended:

- Due to the difference in predicted concentrations from the two dispersion models, with the one being more conservative near-field and the other further afield, it is recommended that passive monitoring of ambient SO_2 and NO_2 be done once the power plant is operational. This should be done bi-annually (summer and winter months) at Lukenya School and the proposed housing estate to ensure ground-level concentrations are within the relevant limits. If after two sampling campaigns (one month in summer and one month in winter) the relevant limits are not exceeded, it won't be necessary to continue with the monitoring.

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AIR QUALITY IMPACT ASSESSMENT FOR A MEDIUM SPEED DIESEL (MSD) THERMAL POWER PLANT NEAR NAIROBI, KENYA

1. INTRODUCTION

Airshed Planning Professionals (Pty) Ltd was contracted by Gulf Power Limited to conduct an air quality study for medium speed diesel (MSD) thermal power plant situated about 30km south east of Nairobi, Kenya. The capacity required is 80 MW (ten 8 MW units).

The main aim of this investigation was to determine the impacts from the proposed power plant on the surrounding environment and human health.

The geographical location of the site is provided in Figure 1-1. The proposed site is situated approximately 30 km south east of Nairobi (the capital town of Kenya).

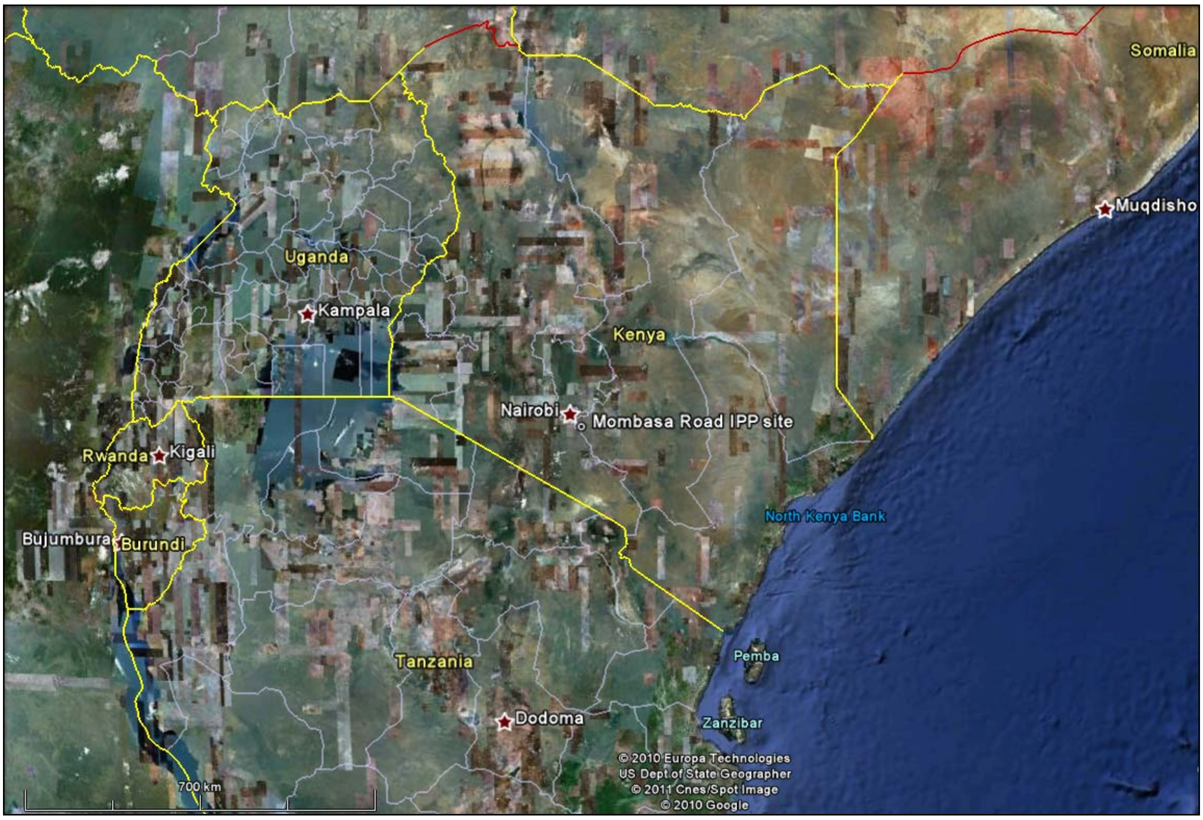

Figure 1-1: Location of the proposed MSD thermal power plant near Nairobi, Kenya.

1.1 Terms of Reference

The tasks involved for the air quality impact assessment for the proposed MSD thermal power plant include:

- Legal review of environmental regulations relating to air quality (Kenya and World Bank);
- Meteorological and topographical data;
- Emissions inventory based on design criteria;
- Dispersion simulation;
- Compliance assessment; and
- Compilation of a comprehensive report.

1.2 Outline of Report

The relevant air quality guidelines and standards are described in Section 2. The methodology is included in Section 3. Dispersion model results for the site are documented in Section 4. Conclusions and recommendations are provided in Section 5.

2. LEGISLATION AND AMBIENT AIR QUALITY CRITERIA

Prior to assessing the impact of the proposed MSD thermal power plant, reference needs be made to the environmental regulations and guidelines governing the emissions and impact of such operations.

Air quality guidelines and standards are fundamental to effective air quality management, providing the link between the source of atmospheric emissions and the user of that air at the downstream receptor site. The ambient air quality guideline values indicate safe daily exposure levels for the majority of the population, including the very young and the elderly, throughout an individual's lifetime. Air quality guidelines and standards are normally given for specific averaging periods. These averaging periods refer to the time-span over which the air concentration of the pollutant was monitored at a location. Generally, five averaging periods are applicable, namely an instantaneous peak, 1-hour average, 24-hour average, 1-month average, and annual average. The application of these standards varies, with some countries allowing a certain number of exceedances of each of the standards per year.

To our knowledge, no environmental legislation has been formulated for Kenya. Typically when no local ambient air quality criteria exists, or are in the process of being developed, reference is made to international health screening criteria. This serves to provide an indication of the severity of the potential impacts from the proposed activities.

The World Bank provides the following guidelines for ambient air quality:

"Emissions do not result in pollutant concentrations that reach or exceed relevant ambient quality guidelines and standards by applying national legislated standards, or in their absence, the current WHO Air Quality Guidelines, or other internationally recognized sources; for example the relevant European Council (EC) Directives."

2.1 EC Directive 2008/50/EC on ambient air quality

Table 2-1 provides the EC limit values for the protection of human health for sulphur dioxide, particulates, and nitrogen dioxide respectively.

Table 2-1: EC limit values for the protection of human health

Pollutant	Hourly (µg/m³)	Daily (µg/m³)	Annual (µg/m³)
Sulphur dioxide	350 [(a)]	125 [(b)]	-
Nitrogen dioxide	200 [(c)]	-	40 [(d)]
Particulate matter	-	50 [(e)]	40 [(f)]

Notes:
(a) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005. Not to be exceeded more than 24 times per calendar year.
(b) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005. Not to be exceeded more than 3 times per calendar year.
(c) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). 1 January 2010. Not to be exceeded more than 18 times per calendar year.
(d) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). 1 January 2010.
(e) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005. Not to be exceeded more than 35 times per calendar year.
(f) EC Directive, 2008/50/EC (http://ec.europa.eu/environment/air/quality/legislation/directive.htm). Already in force since 1 January 2005.

2.2 Adopted Evaluation Criteria for the Power Plant near Nairobi

The EC limit values were adopted for the purpose of this study. These are summarised in Table 2-2.

Table 2-2: Proposed evaluation criteria for the Power Plant near Nairobi [(a)]

Pollutant	1-hour mean (µg/m³)	24-hour average (µg/m³)	Annual mean (µg/m³)
PM_{10}	-	50 (35)	40
SO_2	350 (24)	125 (3)	-
NO_2	200 (18)	-	40

Notes:
(a) Allowable exceedences given in brackets below limit value.

2.3 World Bank Requirements

As of **April 30, 2007**, new versions of the World Bank Group Environmental, Health, and Safety Guidelines (known as the 'EHS Guidelines') are in use. These replace those documents previously published in Part III of the Pollution Prevention and Abatement Handbook and on the IFC website.

The new EHS Guidelines were developed as part of a two and a half year review process. The EHS Guidelines are intended to be 'living documents', and will be updated on a regular basis going forward.

The EHS Guidelines are technical reference documents with general and industry-specific examples of Good International Industry Practice (GIIP).

When host country regulations differ from the levels and measures presented in the EHS Guidelines, projects are expected to achieve whichever is more stringent. If less stringent levels or measures are appropriate in view of specific project circumstances, a full and detailed justification for any proposed alternatives is needed as part of the site-specific environmental assessment. This justification should demonstrate that the choice for any alternate performance levels is protective of human health and the environment.

2.3.1 Emission Limits

Emission guidelines, specified by the World Bank Group in "Thermal Power Plants" for a liquid fuel engine (plant >50 MWth to < 300 MWth) are given in Table 2-3 (World Bank, 2008).

Table 2-3: World Bank emission guidelines for a liquid fuel engine (World Bank, 2008).

Particulates	Sulphur Dioxide	Nitrogen Oxides
mg/Nm³	**% sulphur content**	**mg/Nm³**
50 for non-degraded airshed 30 for degraded airshed	1,170 mg/Nm³ or 2% sulphur content for non-degraded airshed 0.5 % sulphur content for degraded airshed	If bore size diameter < 400 mm: 1,460 If bore size diameter ≥ 400 mm: 1,850 for non-degraded airshed 400 for degraded airshed

3. METHODOLOGY FOR THE AIR QUALITY IMPACT ASSESSMENT FOR THE POWER PLANT

In assessing atmospheric impacts due to the proposed MSD thermal power plant, an emissions inventory was compiled, atmospheric dispersion modelling conducted and predicted air pollutant concentrations evaluated.

Dispersion models compute ambient concentrations as a function of source configurations, emission strengths and meteorological characteristics, thus providing a useful tool to ascertain the spatial and temporal patterns in the ground level concentrations arising from the emissions of various sources. Increasing reliance has been placed on concentration estimates from models as the primary basis for environmental and health impact assessments, risk assessments and emission control requirements. It is therefore important to carefully select a dispersion model for the purpose. The phases undertaken in the impact assessment are described in the following subsections.

3.1 Emissions inventory

The establishment of a comprehensive emission inventory forms the basis for the assessment of the impact of the proposed MSD thermal power plant emissions on the receiving environment. The establishment of an emissions inventory comprises the identification of sources of emission, and the quantification of each source's contribution to ambient air pollution concentrations.

An emission inventory was compiled for the proposed MSD thermal power plant under normal operating conditions.

The following scenario has been simulated:

- 2 segmented stacks (each segmented stack (with a calculated equivalent diameter) consists of a group of 5 stack pipes (one stack pipe per 8MW unit)) at 30m stack heights; and sulphur content of fuel of 2%.

The stack parameters and emission rates are given in Table 3-1. Certain stack parameters were calculated (stack diameter and stack velocity) based on data provided. Total emissions for the proposed MSD thermal power plant are 6086 tpa SO_2, 7569 tpa NO_x and 259 tpa PM_{10}.

Table 3-1: Stack parameters and emissions for the power plant (Wärtsilä emission sheets DBAB555341 and DBAB223880)

Stack parameter	Units	Stack 1 and 2 (combined stack for 5 generators)
Stack height	m	30
Stack diameter	m	2.5
Stack exit temperature	°C	351
Stack exit velocity	m/s	34.1
Stack exit volumetric flow	m³/hr	603 000
SO_2 emission rate (HFO with 2% S)	g/s	96.5
NO_x emission rate	g/s	120
PM_{10} emission rate	g/s	4.1

3.2 Emissions assessment

SO_2 emissions are generated during oil combustion from the oxidation of sulphur contained in the fuel. Uncontrolled SO_2 emissions are almost entirely dependent on the sulphur content of the fuel. Comparison is made to emission limits in Table 3-2.

- Sulphur dioxide (SO_2), nitrogen oxides (NO_x) and particulate matter (PM_{10}) are equal to the World Bank Group (WBG) emissions guidelines.

Table 3-2: Comparison to emission limits

Pollutant	World Bank Group April 30, 2007	Emissions from the proposed MSD thermal power plant
SO_2	2 % S or 1,170 mg/Nm³	2 % S (1,170 mg/Nm³)
NO_x	If bore size diameter [mm] < 400 1,460 mg/Nm³ If bore size diameter [mm] > or = 400 1,850 mg/Nm³	1,460 mg/Nm³
PM_{10}	50 mg/Nm³	50 mg/Nm³

3.3 Selection of dispersion model

For the purpose of the current study, it was decided to use both the AERMOD and the ADMS 4 dispersion models.

ADMS 4 (Atmospheric Dispersion Modelling System version 4) developed by the Cambridge Environmental Research Consultants (CERC). CERC was established in 1986, with the aim of making use of new developments in environmental research from Cambridge University and elsewhere for practical purposes. This model simulates a wide range of buoyant and passive releases to the atmosphere either individually or in combination. It has been the subject of a number of inter-model comparisons (CERC 2000, Hall et al 2001), one conclusion of which is that it tends provide conservative values under unstable atmospheric conditions in that, in comparison to the older regulatory models, it predicts higher concentrations close to the source.

ADMS 4 is a new generation air dispersion model which means that it differs from the regulatory models traditionally used in a number of aspects, the most important of which are the description of atmospheric stability as a continuum rather than discrete classes (the atmospheric boundary layer properties are described by two parameters; the boundary layer depth and the Monin-Obukhov length, rather than in terms of the single parameter Pasquill Class) and in allowing more realistic asymmetric plume behaviour under unstable atmospheric conditions. Dispersion under convective meteorological conditions uses a skewed Gaussian concentration distribution (shown by validation studies to be a better representation than a symmetric Gaussian expression).

Gaussian-plume models are best used for near-field applications where the steady-state meteorology assumption is most likely to apply. The AERMET/AERMOD dispersion model suite was chosen for the current study as it is the new regulatory model that has replaced the US-EPA Industrial Source Complex Model Gaussian plume model. AERMET uses more comprehensive meteorological data sets including upper air data. The model also has a terrain pre-processor (AERMAP) for including a topography into the model. The AERMET/AERMOD suite was developed with the support of the AMS/EPA Regulatory Model Improvement Committee (AERMIC), whose objective has been to include state-of the-art science in regulatory models.

Similar to the ISCST3 a disadvantage of the model is that spatial varying wind fields, due to topography or other factors cannot be included. Also, the range of uncertainty of the model predictions could to be -50% to 200%. The accuracy improves with fairly strong wind speeds and during neutral atmospheric conditions.

There will always be some error in any geophysical model, but it is desirable to structure the model in such a way to minimise the total error. A model represents the most likely outcome of an ensemble of experimental results. The total uncertainty can be thought of as the sum of three components: the uncertainty due to errors in the model physics; the uncertainty due to data errors; and the uncertainty due to stochastic processes (turbulence) in the atmosphere.

The stochastic uncertainty includes all errors or uncertainties in data such as source variability, observed concentrations, and meteorological data. Even if the field instrument accuracy is excellent, there can still be large uncertainties due to unrepresentative placement of the instrument (or taking of a sample for analysis). Model evaluation studies suggest that the data input error term is often a major contributor to total uncertainty. Even in the best tracer studies, the source emissions are known only with an accuracy of ±5%, which translates directly into a minimum error of that magnitude in the model predictions. It is also well known that wind direction errors are the major cause of poor agreement, especially for relatively short-term predictions (minutes to hourly) and long downwind distances. All of the above factors contribute to the inaccuracies not even associated with the mathematical models themselves.

Input data types required for the both the ADMS and the AERMOD models include: source data, meteorological data (pre-processed by the AERMET model for AERMOD), terrain data and information on the nature of the receptor grid.

3.3.1 Meteorological Requirements

Meteorological mechanisms govern the dispersion, transformation and eventual removal of pollutants from the atmosphere (Pasquill and Smith, 1983; Godish, 1990). The extent to which pollution will accumulate or disperse in the atmosphere is dependent on the degree of thermal and mechanical turbulence within the earth's boundary layer. Dispersion comprises vertical and horizontal components of motion. The vertical component is defined by the stability of the atmosphere and the depth of the surface mixing layer. The horizontal dispersion of pollution in the boundary layer is primarily a function of the wind field and atmospheric stability regime. The wind speed determines both the distance of downwind transport and the rate of dilution as a result of plume 'stretching'. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness. The wind direction, and the variability in wind direction, determines the general path pollutants will follow, and the extent of cross-wind spreading (Oke, 1990).

Pollution concentration levels therefore fluctuate in response to changes in atmospheric stability, to concurrent variations in the mixing depth, and to shifts in the wind field. Spatial variations, and diurnal and seasonal changes, in the wind field and stability regime are functions of atmospheric processes operating at various temporal and spatial scales. Atmospheric processes at macro- and meso-scales need therefore be taken into account in order to accurately parameterise the atmospheric dispersion potential of a particular area.

AERMOD requires two specific input files generated by the AERMET pre-processor. AERMET is designed to be run as a three-stage processor and operates on three types of data (upper air data, on-site measurements, and the national meteorological database). Since the model was designed for the USA environment, various difficulties are found compiling the required dataset for the other environments. The main data shortfalls include the following:

- Meteorological databases do not accommodate all the parameters required by AERMET.
- Surface meteorological stations seldom measure all the required parameters (such as solar radiation, cloud cover, humidity).

The Lakes Environmental processed MM5 meteorological data was used as input to AERMOD and ADMS (Table 3-3). MM5 is a widely-used three-dimensional numerical meteorological model contains non-hydrostatic dynamics, a variety of physics options for parameterizing cumulus clouds, microphysics, the planetary boundary layer and atmospheric radiation.

Table 3-3: Summary of meteorological data

Parameters	Met data
Data Period	2005-2009
Location	1.458131 S 37.004422 E
Wind Direction	100%
Wind Speed	100%
Temperature	100%
Relative Humidity	100%
Pressure	100%

3.3.2 Source Data Requirements

AERMOD and ADMS are able to model point, area, volume and line sources. The stacks from the power plant were modelled as point sources.

3.3.3 Receptor Grid

The dispersion of pollutants emanating from the site was modelled for an area covering 12 km (north-south) by 12 km (east-west). The area was divided into a grid matrix with a resolution of 120 m by 120 m. The models simulate ground-level concentrations for each of the receptor grid points.

3.3.4 Surface Wind Field

The vertical dispersion of pollution is largely a function of the wind field. The wind speed determines both the distance of downward transport and the rate of dilution of pollutants. The generation of mechanical turbulence is similarly a function of the wind speed, in combination with the surface roughness.

Wind roses comprise 16 spokes which represent the directions from which winds blew during the period. The colours reflect the different categories of wind speeds, the grey area, for example, representing winds of 1 m/s to 3 m/s. The dotted circles provide information regarding the frequency of occurrence of wind speed and direction categories. Each dotted circle represents 5% frequency of occurrence. The figure given in the centre of the circle described the frequency with which calms occurred, i.e. periods during which the wind speed was below 1 m/s.

3.3.5 Model input and execution

Input into the dispersion models includes prepared meteorological data, topographical data, source data, information on the nature of the receptor grid and emissions input data. The model inputs were verified before the models were executed.

3.3.6 Plotting of model outputs

Simulated outputs for SO_2 (hourly and daily), PM_{10} (daily and annual) and NO_2 (hourly and annual) were plotted.

3.3.7 Compliance analysis and impact assessment

The predicted air pollution concentrations were compared to current air quality limits to facilitate compliance and impact assessments. These concentrations were summarised and form the basis of the compliance assessment and evaluation.

3.4 Assumptions and limitations

In interpreting the study findings it is important to note the limitations and assumptions on which the assessment was based. The most important assumptions and limitations of the air quality impact assessment are summarised as follows:

Assumptions

- Impacts were based on estimated stack parameters for the segmented stack (each segmented stack (with a calculated equivalent diameter and velocity) consists of a group of 5 stack pipes) outlet; and
- A sulphur content of the fuel of 2 % was assumed.

Limitations

- Measured meteorological data was not available for the study area. Use was therefore made of Lakes Environmental processed MM5 data.

4. AIR QUALITY IMPACT ASSESSMENT FOR THE MSD THERMAL POWER PLANT SITUATED NEAR NAIROBI, KENYA

4.1 Surface Wind Field

The period, day-time and night-time wind roses for the study area are provided in Figure 4-1.

The flow field is dominated by northeasterly winds with infrequent winds noted to occur from the west. During the day-time, the predominant wind flow is from the northeast, associated with strong winds (5 - 10 m/s). During night-time the wind velocity is much lower, with the prevailing wind still from the northeast. This is typical of night-time airflow when calm periods and low wind speeds are generally more prevalent.

4.2 Topography

The topography for the study area is provided in Figure 4-2. The terrain is fairly flat in the vicinity of the site, with an elevation of approximately 1516 m. Lukenya hill is located over 5km east of the site at an elevation of approximately 1828 m.

ADMS models the effect of complex terrain by changing the plume trajectory and dispersion to account for disturbances in the airflow due to the terrain. It is not always necessary to include the effects of surrounding terrain in a modelling calculation. Usually terrain effects are only included if the gradient exceeds 1:10. The influence of the terrain will vary with the source height and position and local meteorology.

AERMAP (AERMOD's terrain preprocessor) considers significant terrain elevations to include all the terrain that is at or above a 10% slope (gradient of 1:10) from each and every receptor.

In the vicinity of the site (5 km from the site) the gradient does not exceed 1:10. Lukenya hill 5km east of the site however has a gradient of 1:6.6.

4.3 Sensitive Receptors

Sensitive receptors in the vicinity of the site include the Athi River (~1.5 km west of the site) and Kitengala (~4.4 km south west of the site), Figure 4-3. Lukenya School and Daystar University are located ~ 5 km east-northeast of the site, at the base of the Lukenya Hill. A housing estate is located only 500 m from the site. A Flower farm is located 4 km south east of the site.

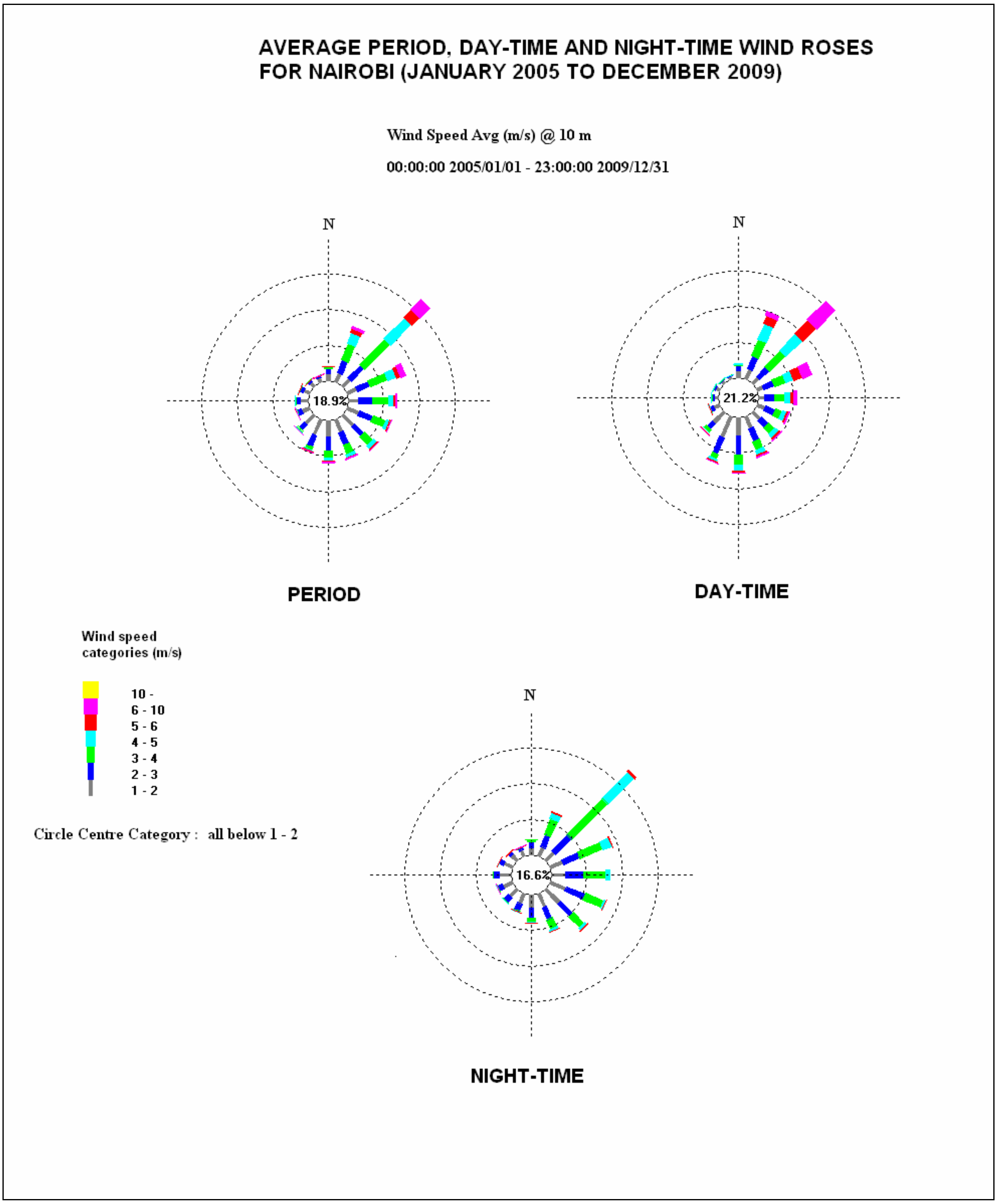

Figure 4-1: Period, day-time and night-time wind roses for Nairobi (from MM5) for the period 2005 to 2009.

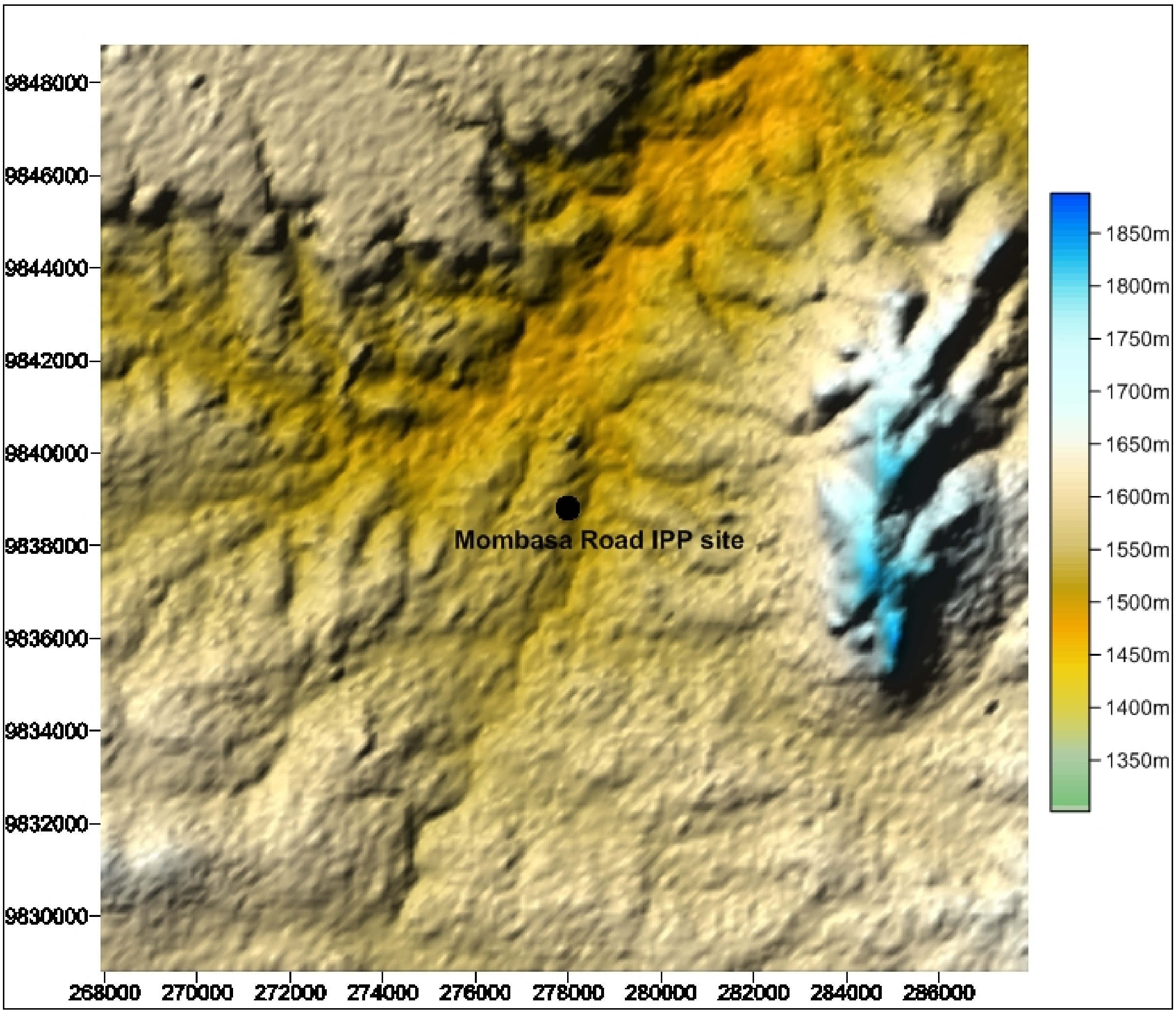

Figure 4-2: Topography for the study area.

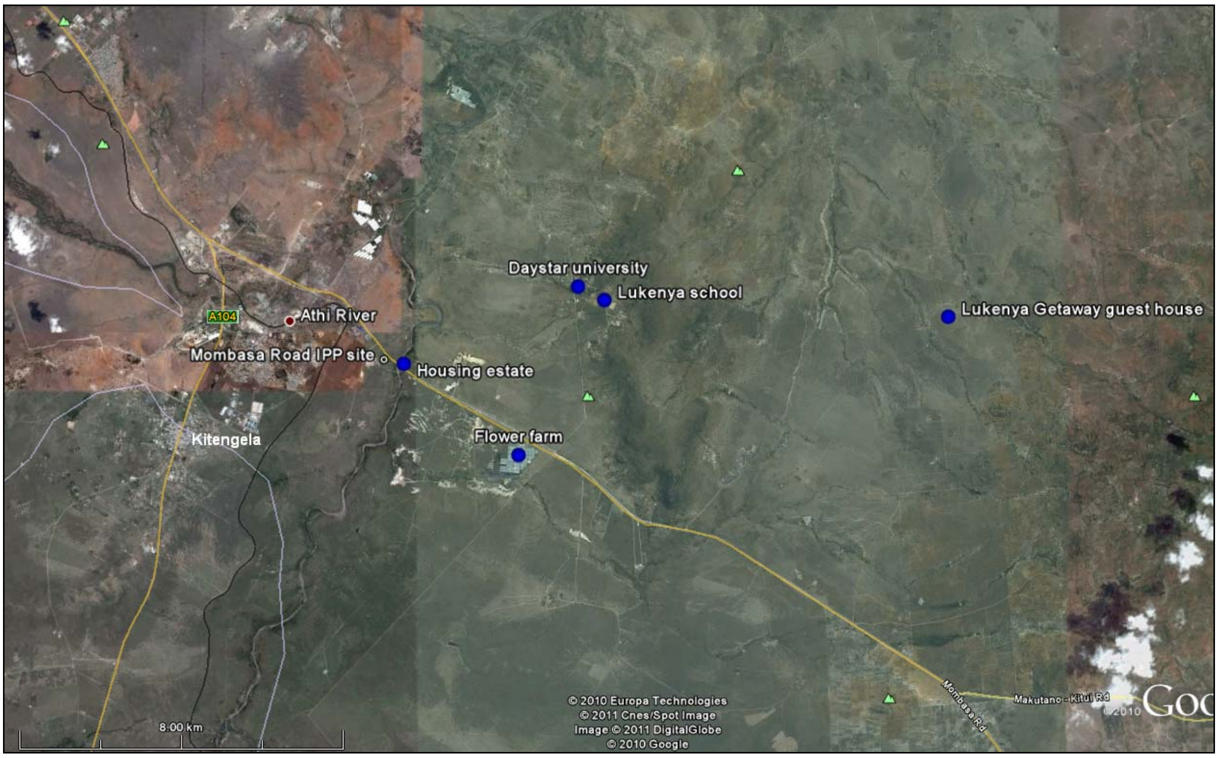

Figure 4-3: Sensitive receptor areas at the proposed site near Nairobi, Kenya.

4.4 Dispersion Simulation Results

The focus for the dispersion modelling study is to provide an understanding of the magnitude and spatial impacts at the site.

The dispersion results are summarised in Table 4-1. The predicted ground level concentrations for SO_2, NO_2 and PM_{10} are shown for Athi River, the Housing Estate and Lukenya School. Daystar University is not listed for it had similar impacts to Lukenya School. The frequency of exceedance (FOE) provides a number of times (hours or days) where the limit may be exceeded. Should this limit be exceeded for more than the allowable number of times the predicted impacts are in non-compliance with the limit.

Figures 4-4 to 4-20 provide a birds-eye view of the spatial impacts from the proposed MSD thermal power plant, clearly showing the areas (footprint) where the relevant guidelines are predicted to be exceeded. Plots provided for the study are given in Table 4-2.

Ground level concentration (GLC) isopleths plots presented in this section depict interpolated values from the concentrations predicted by the models for each of the receptor grid points specified. Plots reflecting hourly (daily) averaging periods contain only the 99.99th (99.73th) percentile of predicted ground level concentrations, for those averaging periods, over the entire period for which simulations were undertaken. It is therefore possible that even though a high hourly (daily) average concentration is predicted to occur at certain locations, that this may only be true for one hour (day) during the year.

Table 4-1: Summary of the predicted ground level concentrations.

Pollutant	Averaging period	EC limits (µg/m³)	Predicted concentrations (µg/m³) and frequencies of exceedences at the sensitive receptors					
			Athi River		Housing Estate		Lukenya School	
			ADMS	AERMOD	ADMS	AERMOD	ADMS	AERMOD
SO_2	Highest hourly	350	160	90	300	130	55	**800**
	Hourly FOE	24	-	-	-	-	-	**24**
	Highest daily	125	40	23	27	27	5	60
	Daily FOE	3	-	-	-	-	-	-
NO_2	Highest hourly	200	100	55	175	75	34	**450**
	Hourly FOE	18	-	-	-	-	-	**24**
	Annual average	40	5.5	4	0.5	5	0.3	4
PM_{10}	Highest daily	50	1.7	1	1	1.2	0.2	2.5
	Annual average	40	0.18	0.14	0.02	0.18	0.01	0.13

Notes: FOE – Frequency of Exceedance of EC limits shown in bold.

Table 4-2: Isopleth plots presented in the current section.

Pollutant	Averaging Period	Figure
SO_2	Highest hourly (ADMS)	4-4
	Highest hourly (AERMOD)	4-5
	Highest hourly frequency of exceedence (ADMS)	4-6
	Highest hourly frequency of exceedence (AERMOD)	4-7
	Highest daily (ADMS)	4-8
	Highest daily (AERMOD)	4-9
	Highest daily frequency of exceedence (AERMOD)	4-10
NO_2	Highest hourly (ADMS) (assuming 50% NO_x as NO_2)	4-11
	Highest hourly (AERMOD) (assuming 50% NO_x as NO_2)	4-12
	Highest hourly frequency of exceedence (ADMS)	4-13
	Highest hourly frequency of exceedence (AERMOD)	4-14
	Annual average (ADMS)	4-15
	Annual average (AERMOD)	4-16
PM_{10}	Highest daily (ADMS)	4-17
	Highest daily (AERMOD)	4-18
	Annual average (ADMS)	4-19
	Annual average (AERMOD)	4-20

4.4.1 Sulphur Dioxide

For the ADMS dispersion model, the predicted SO_2 concentrations exceed the EC hourly limit of 350 µg/m³ (Figure 4-4), but not at any of the identified sensitive receptors (Table 4-1). The frequency of exceedence (i.e. the number of hours in a year where the limit is exceeded) is more than 24 hours, but only for a small impact area in the vicinity of the proposed plant (Figure 4-6). The area of impact does not appear to be inhabited. The EC daily SO_2 limit of 125 µg/m³ is not predicted to be exceeded (Figure 4-8).

For the AERMOD dispersion model, the predicted SO_2 concentrations exceed both the EC hourly SO_2 limit of 350 µg/m³ and the EC daily SO_2 limit of 125 µg/m³ (Figures 4-5 and 4-9). The only sensitive receptor where the hourly limit is exceeded is Lukenya school (Table 4-1). Exceedences are predicted at Lukenya Hill where the elevation increases. The limit is exceeded for 24 hours at the school, matching the allowable frequency of exceedence (Figure 4-7). Over a 24-hour (daily) average the limit is exceeded less than 3 days within the dispersion modelling area (Figure 4-10).

4.4.2 Nitrogen Dioxide

For the ADMS dispersion model, the predicted NO_2 concentrations are within the EC limit of 200 µg/m³ at the identified sensitive receptors but exceed the limit in the vicinity of the proposed site (Figure 4-11). The frequency of exceedence (i.e. the number of hours in a year where the limit is exceeded) is more than 18 hours, but only for a small impact area in the vicinity of the proposed plant (Figures 4-13). The area of impact does not appear to be inhabited. This is based on the assumption that 50% of the predicted NO_x concentrations are NO_2 (HMP, 1993). The EC annual NO_2 limit of 40 µg/m³ is not predicted to be exceeded at any location (Figure 4-15).

For the AERMOD dispersion model, the predicted NO_2 concentrations exceed the EC hourly NO_2 limit of 200 µg/m³ at the sensitive receptors of Lukenya School and Daystar University (Figure 4-12 and Table 4-1). The frequency of exceedence is 24 hours at the school and 1 hour at the university (Figure 4-14). Over an annual average no exceedences of the EC limit are predicted.

4.4.3 Particulates

PM_{10} concentrations as reflected in Figures 4-17 and 4-18 (highest daily) and Figures 4-19 and 4-20 (annual average) are very low and well within the EC limits.

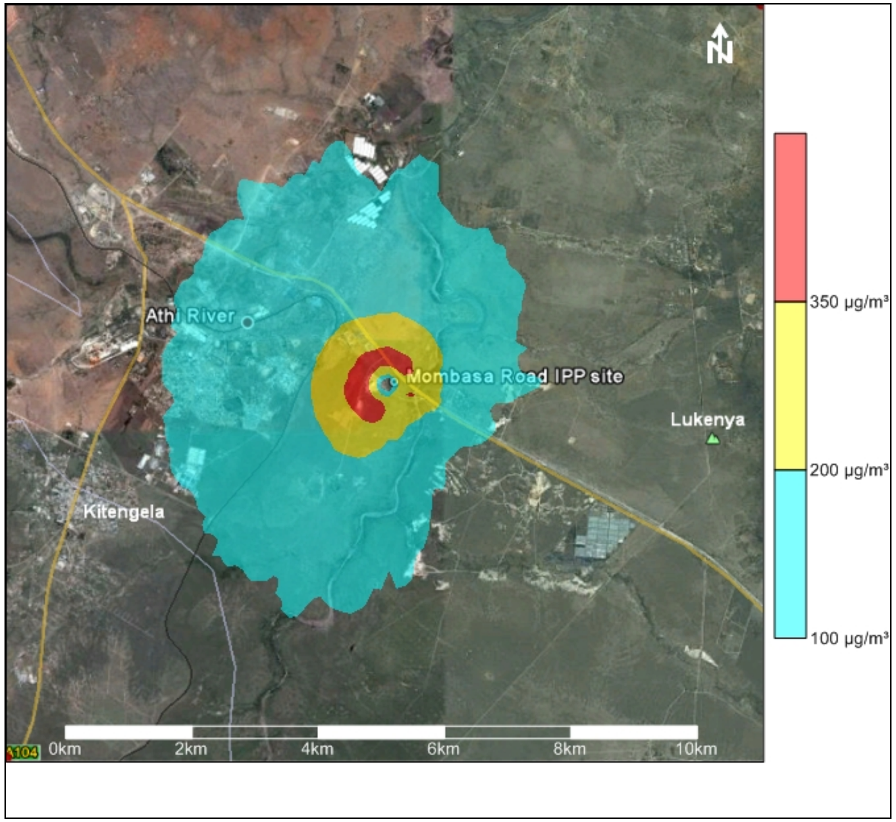

Figure 4-4: Highest hourly average SO_2 predicted ground level concentrations (ADMS).

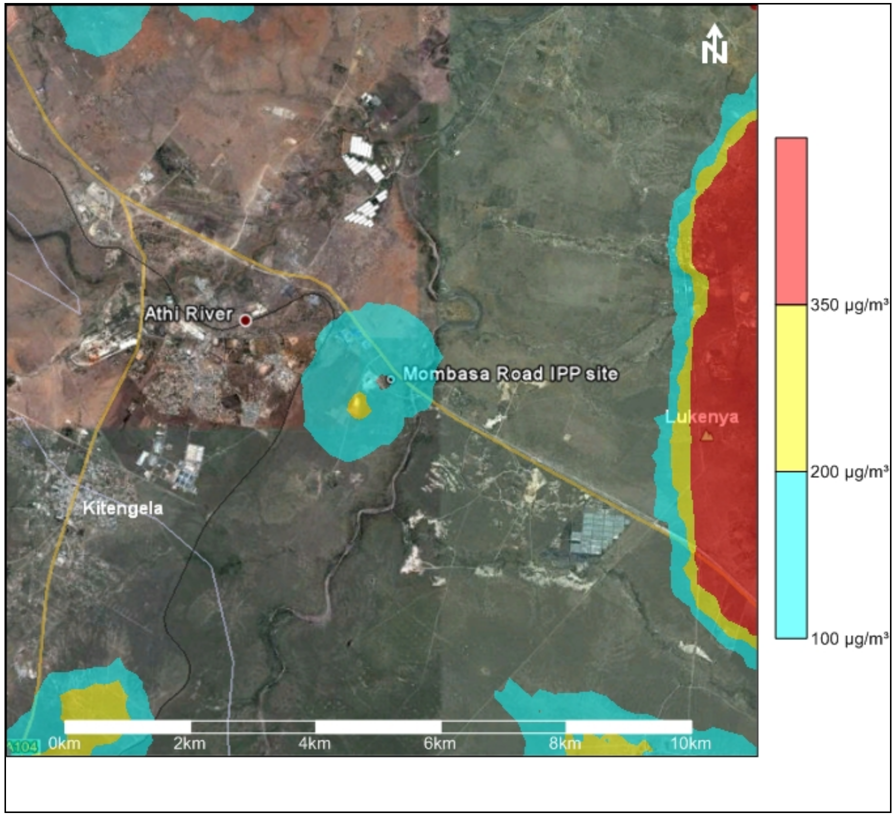

Figure 4-5: Highest hourly average SO_2 predicted ground level concentrations (AERMOD).

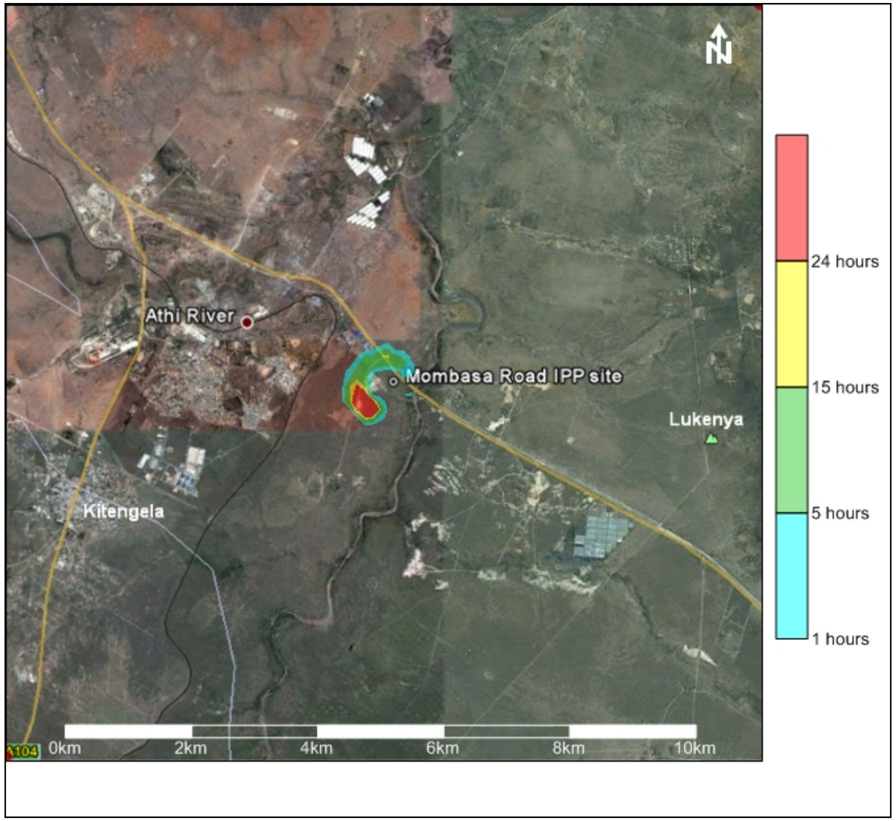

Figure 4-6: Predicted frequency of exceedance of the EC hourly SO_2 limit of 350 µg/m³ (ADMS).

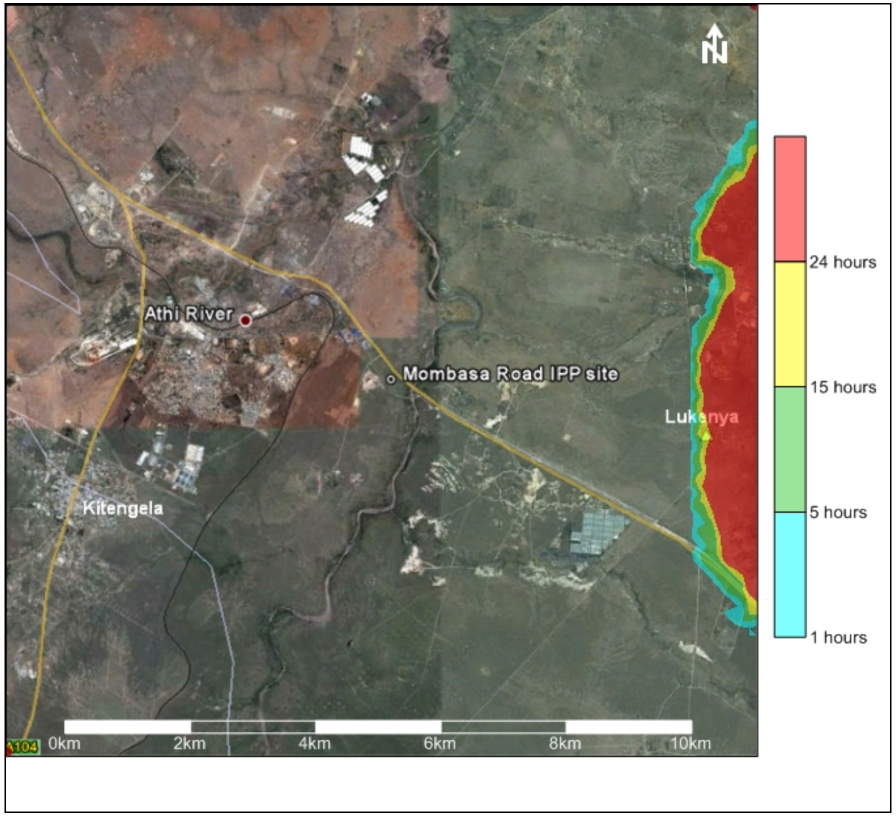

Figure 4-7: Predicted frequency of exceedance of the EC hourly SO_2 limit of 350 µg/m³ (AERMOD).

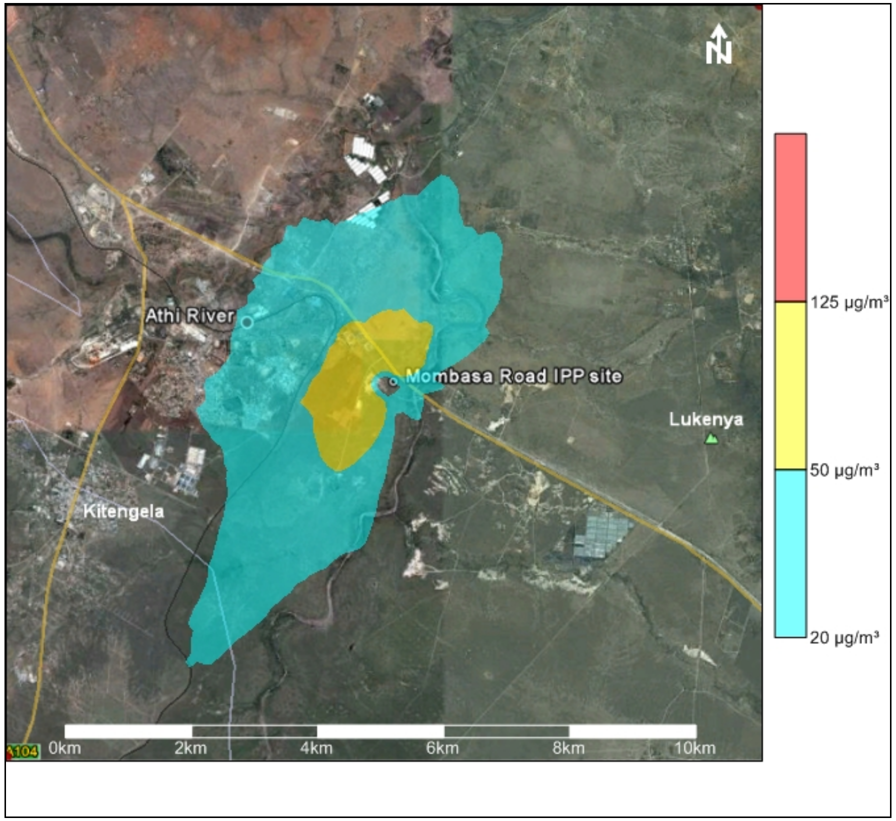

Figure 4-8: Highest daily average SO_2 predicted ground level concentrations (ADMS).

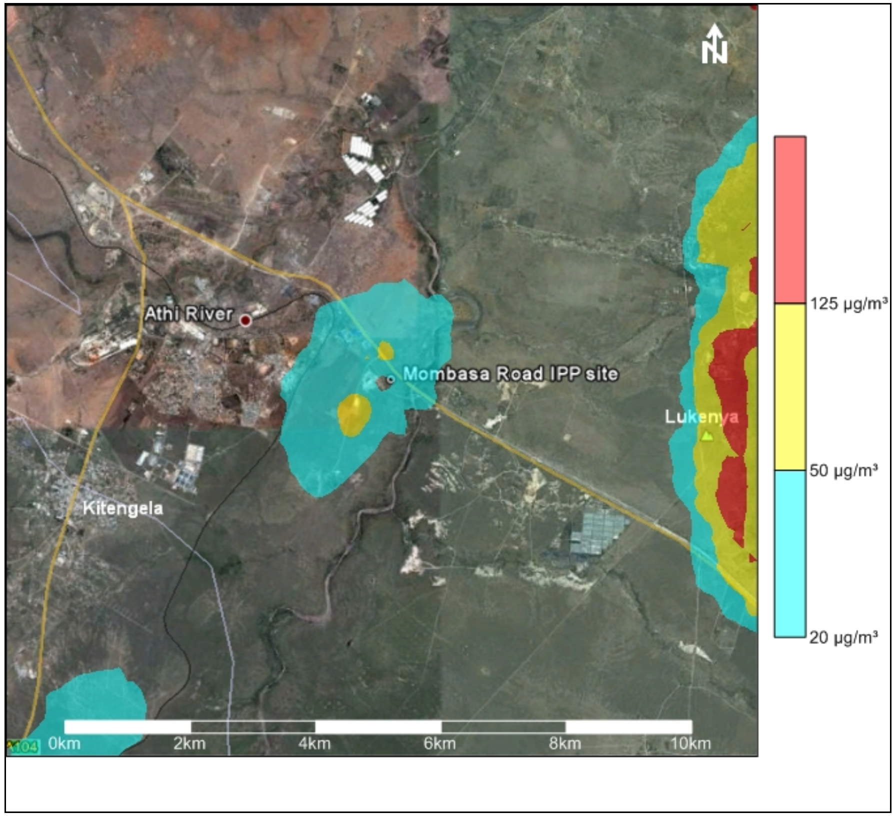

Figure 4-9: Highest daily average SO_2 predicted ground level concentrations (AERMOD).

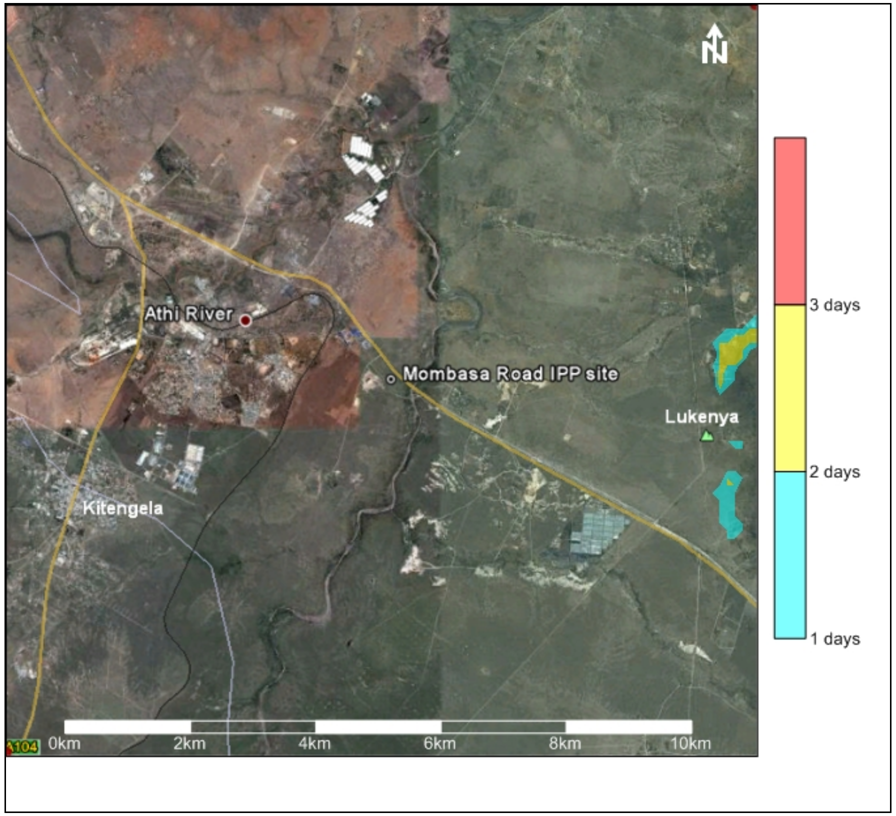

Figure 4-10: Predicted frequency of exceedance of the EC daily SO_2 limit of 125 µg/m³ (AERMOD).

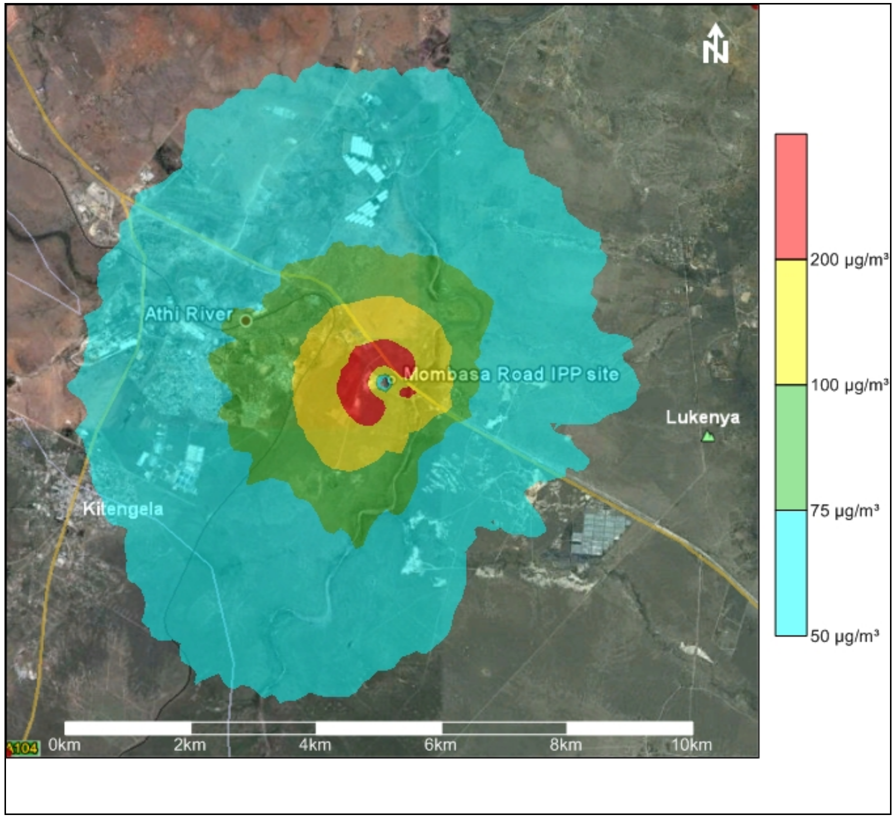

Figure 4-11: Highest hourly average NO_2 predicted ground level concentrations – assuming 50% NO_x as NO_2 (ADMS).

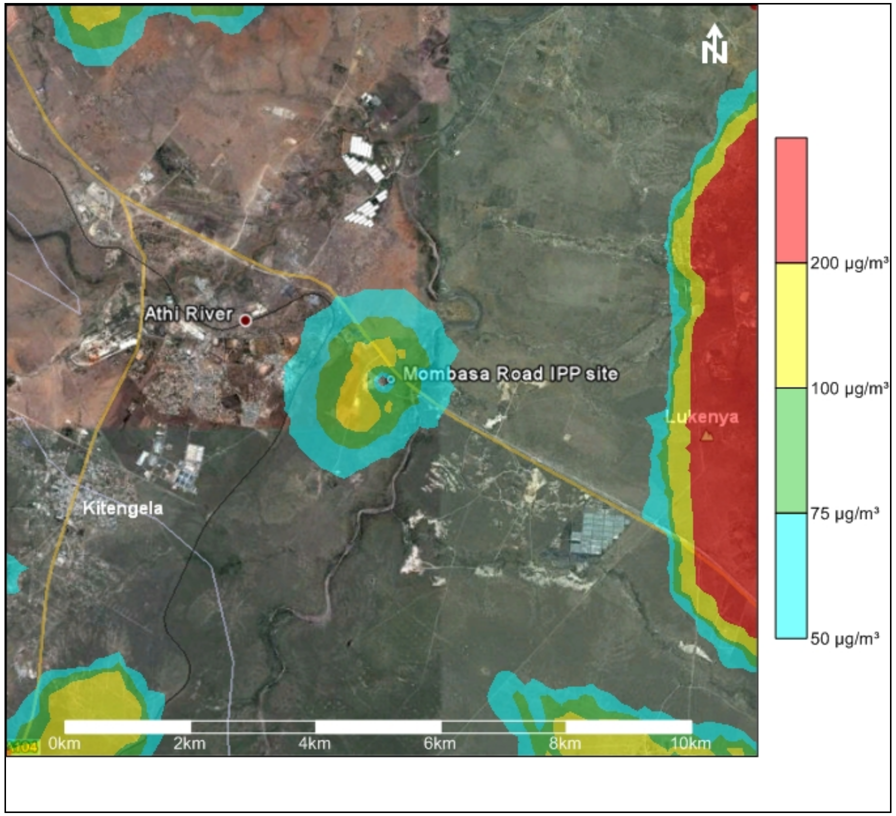

Figure 4-12: Highest hourly average NO_2 predicted ground level concentrations – assuming 50% NO_x as NO_2 (AERMOD).

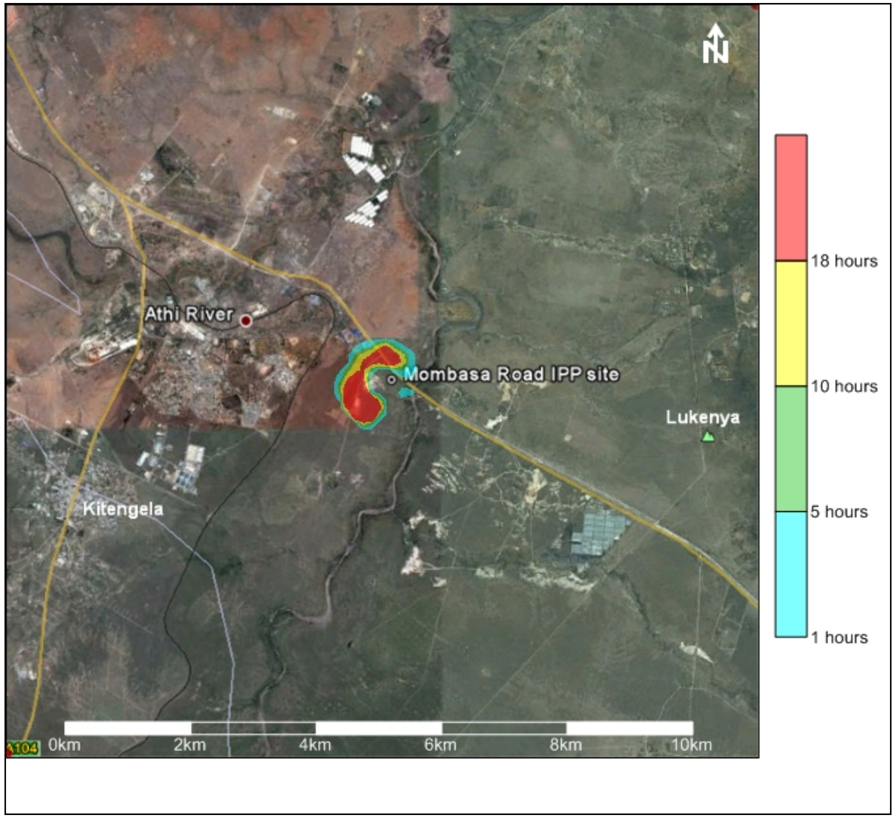

Figure 4-13: Predicted frequency of exceedance of the EC hourly NO_2 limit of 200 µg/m³ (ADMS).

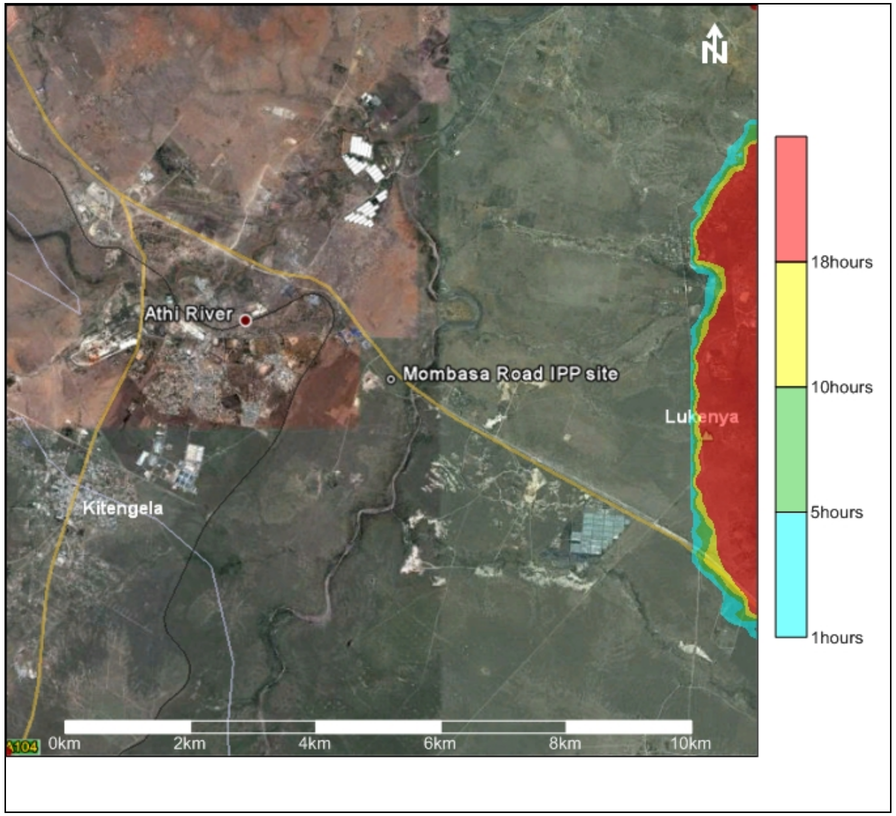

Figure 4-14: Predicted frequency of exceedance of the EC hourly NO_2 limit of 200 µg/m³ (AERMOD).

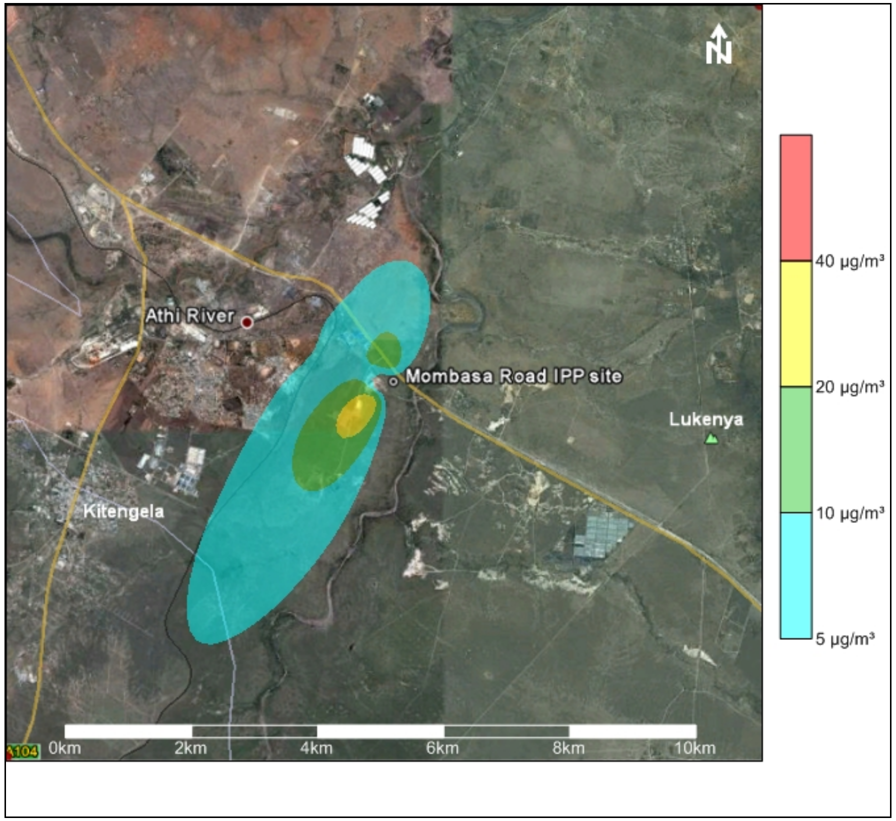

Figure 4-15: Annual average NO_2 predicted ground level concentrations (ADMS).

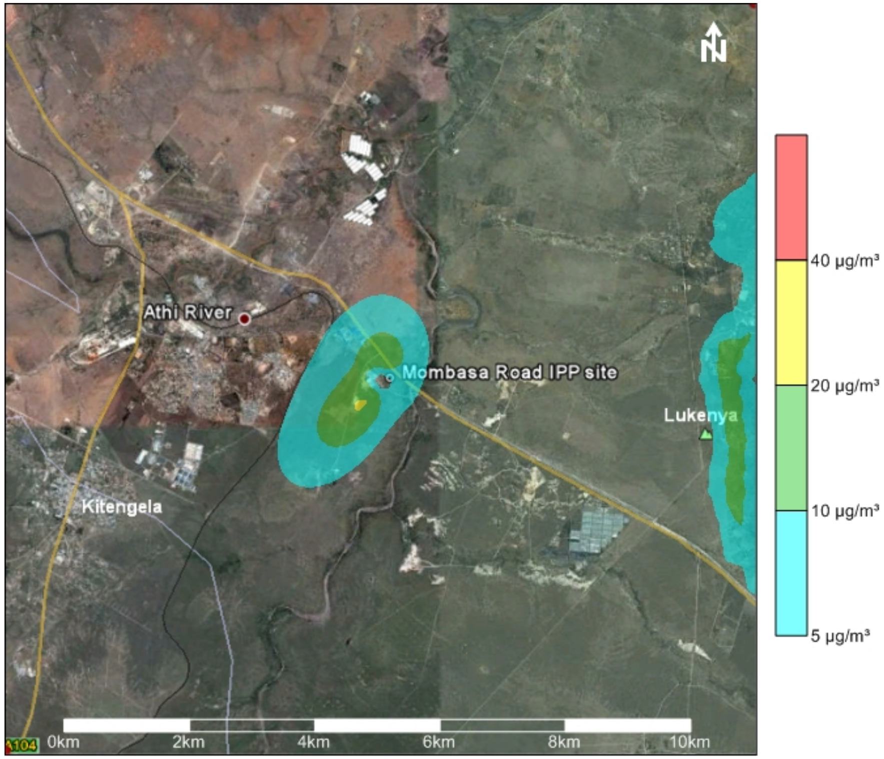

Figure 4-16: Annual average NO_2 predicted ground level concentrations (AERMOD).

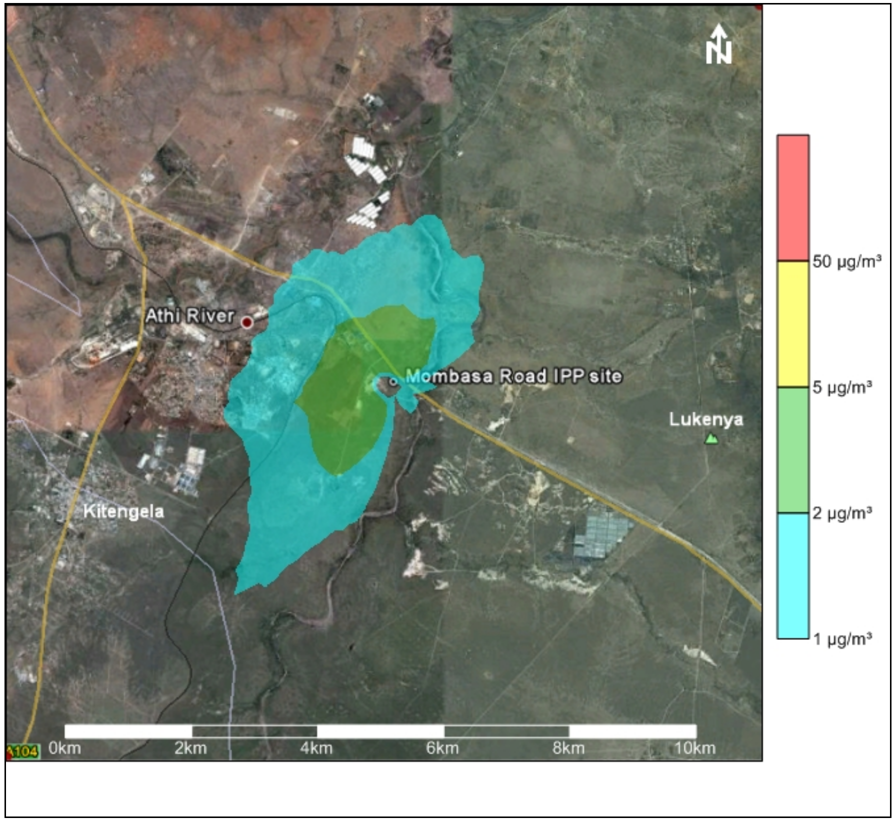

Figure 4-17: Highest daily average PM_{10} predicted ground level concentrations (ADMS).

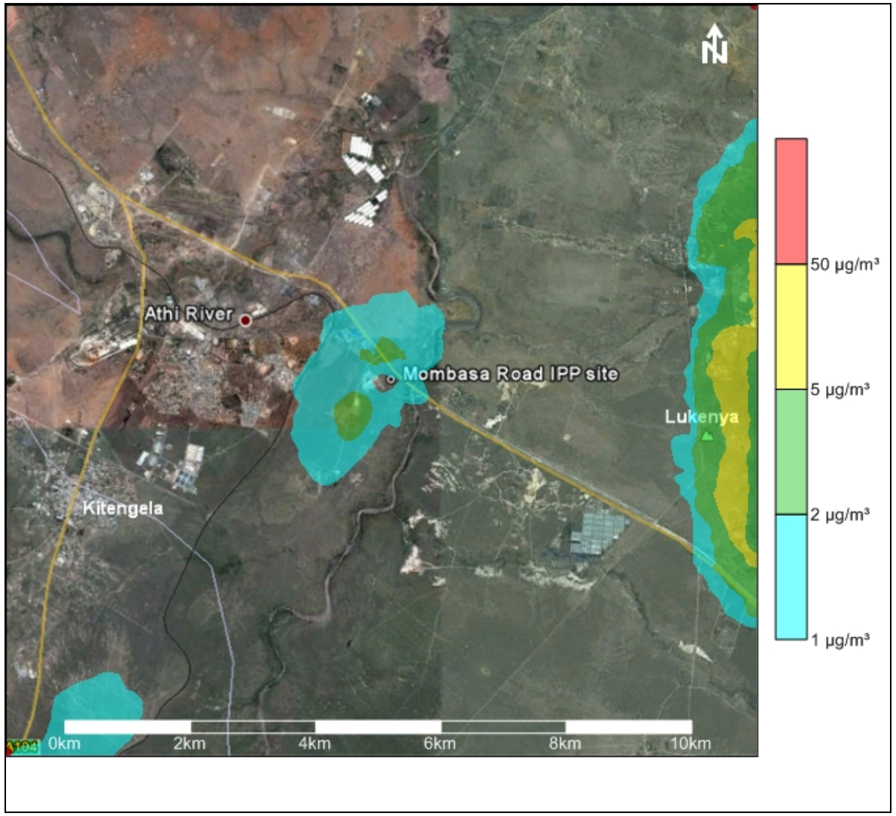

Figure 4-18: Highest daily average PM_{10} predicted ground level concentrations (AERMOD).

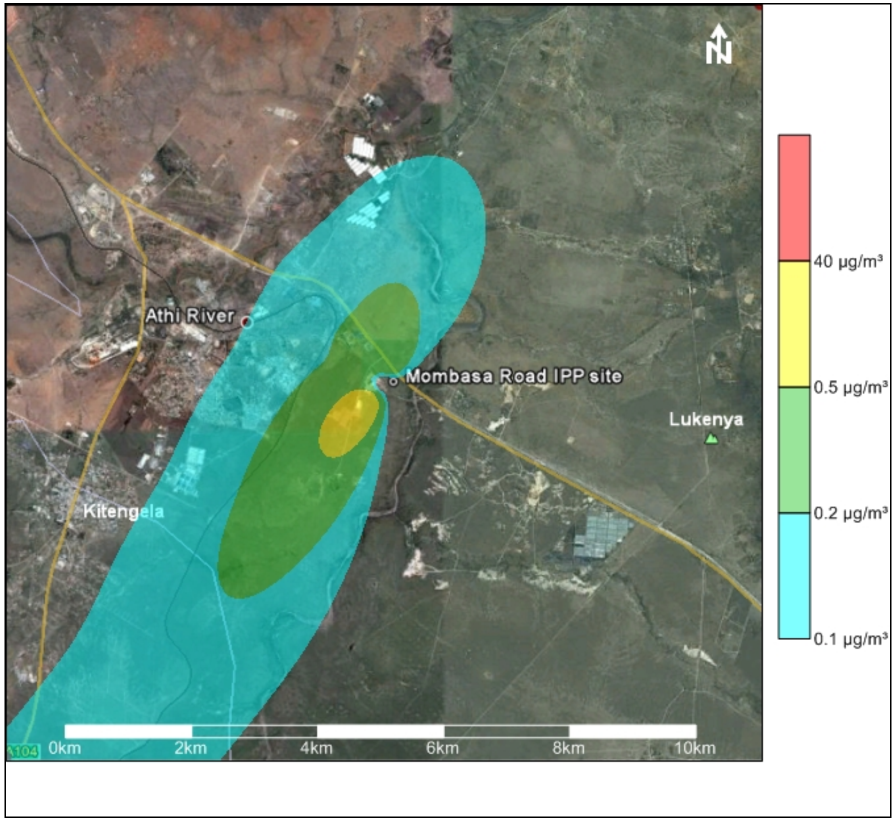

Figure 4-19: Annual average PM_{10} predicted ground level concentrations (ADMS).

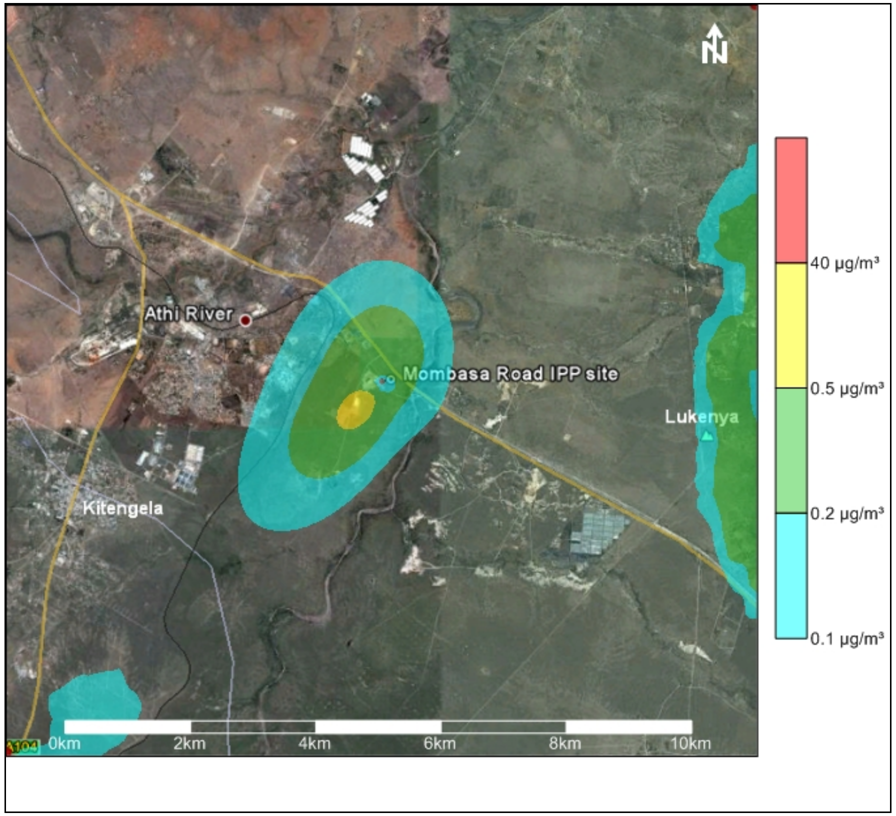

Figure 4-20: Annual average PM_{10} predicted ground level concentrations (AERMOD).

5. CONCLUSIONS AND RECOMMENDATIONS

The main aim of this investigation was to determine the impacts from the proposed power plant on the surrounding environment and human health. The following scenario was modelled:

- 2 segmented stacks (each segmented stack (with a calculated equivalent diameter) consists of a group of 5 stack pipes (one stack pipe per 8MW unit)) at 30m stack heights; and sulphur content of fuel of 2%.

5.1 Conclusions

- At the nearest sensitive receptor of Athi River and the housing estate, none of the EC limit values are predicted to be exceeded.
- AERMOD predicts exceedences of the SO_2 and NO_2 hourly limits at Lukenya school with the frequency of exceedence being equal to the limit for SO_2 and slightly over the limit for NO_2
- ADMS is slightly more conservative than AERMOD in the vicinity of the plant, thus near-site with AERMOD being more conservative further away at the elevated areas such as Lukenya Hill area.

5.2 Recommendations

- Due to the difference in predicted concentrations from the two dispersion models, with the one being more conservative near-field and the other further afield, it is recommended that passive monitoring of ambient SO_2 and NO_2 be done once the power plant is operational. This should be done bi-annually (summer and winter months) at Lukenya School and the proposed housing estate to ensure ground-level concentrations are within the relevant limits. If after two sampling campaigns (one month in summer and one month in winter) the relevant limits are not exceeded, it won't be necessary to continue with the monitoring.

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